ENGINEERING STANDARD

FOR

PROCESS DESIGN

OF

GAS (VAPOR)-LIQUID SEPARATORS

ORIGINAL EDITION

MAY 1997

This standard specification is reviewed and updated by the relevant technical committee on Jan. 2006. The approved modifications are included in the present issue of IPS.

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APPENDICES:

0. INTRODUCTION

"Process Design of Separators" is broad and contains various subjects of paramount importance. Therefore a group of Process Engineering Standard specifications are prepared to cover the subject of mechanical separators.

This group includes the following standards:

STANDARD CODE	STANDARD TITLE
IPS-E-PR-880	"Process Design of Gas (Vapor)-Liquid Separators"
IPS-E-PR-895	"Process Design of Solid-Liquid Separators"

This Standard Specification covers:

"PROCESS DESIGN OF GAS (VAPOR) - LIQUID SEPARATORS"

1. SCOPE

This Engineering Standard Specification covers minimum requirements for the process design (including criteria for type selection) of gas (vapor)-liquid separators used in the production of the oil and/or gas, refineries and other gas processing and petrochemical plants. For the purpose of this Standard, separation techniques are defined as, those operation, which isolate specific immiscible ingredients of a mixture mechanically, i.e., without a chemical reaction or a mass transfer process taking place.

For design of inlet and outlet nozzles and vessel internals refer to Engineering Standard IPS-G-ME-150, "Towers, Reactors, Pressure Vessels & Internals" unless otherwise specified in this Standard.

Note:

This standard specification is reviewed and updated by the relevant technical committee on Jan. 2006. The approved modifications by T.C. were sent to IPS users as amendment No. 1 by circular No. 276 on Jan. 2006. These modifications are included in the present issue of IPS.

2. REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

API (AMERICAN PETROLEUM INSTITUTE)

API Spec. 12J	"Specification for Oil and Gas Separators", 7th. Ed., Oct. 1989

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-E-GN-100	"Units"
IPS-E-PR-460	"Process Design of Flare and Blowdown Systems"
IPS-G-ME-150	"Towers, Reactors, Pressure Vessels & Internals"

3. DEFINITIONS AND TERMINOLOGY

The following is a glossary of terms used in the gas (vapor)-liquid separator and separation technology.

3.1 Coalescer

A mechanical process vessel with wettable, high-surface area packing on which liquid droplets consolidate for gravity separation from a second phase (for example gas or immiscible liquid).

3.2 Control Volume

A certain liquid volume necessary for control purposes and for maintaining the velocity limit requirement for degassing and to counter foam in separators.

3.3 Conventional Gas-Liquid Separator

In this Standard, the term "Conventional Gas-Liquid Separator" is referred to vertical or horizontal separators in which gas and liquid are separated by means of gravity settling with or without a mist eliminating device.

3.4 Disengaging Height

The height provided between bottom of the wire-mesh pad and liquid level of a vapor-liquid separator.

3.5 Fabric Filter

Commonly termed "bag filters" or "baghouses", are collectors in which dust is removed from the gas stream by passing the dust-laden gas through a fabric of some type.

3.6 Flash Tank

A vessel used to separate the gas evolved from liquid flashed from a higher pressure to a lower pressure.

3.7 Hold-Up Time

A time period during which the amount of liquid separated in a gas-liquid separator is actually in the vessel for the purpose of control or vapor separation.

3.8 Knock-Out

A separator used for a bulk separation of gas and liquid.

3.9 Line Drip

A device typically used in pipelines with very high gas-to-liquid ratios to remove only free liquid from a gas stream,and not necessarily all the liquid.

3.10 Demister Mist Extractor

A device installed in the top of scrubbers, separators, tray or packed vessels, etc. to remove liquid droplets entrained in a flowing gas stream.

3.11 Scrubber

A type of separator which has been designed to handle flow streams with unusually high gas-to-liquid ratios.

3.12 Slug Catcher

A particular separator design able to absorb sustained in-flow of large liquid volumes at irregular intervals.

3.13 Target Efficiency

The fraction of particles or droplets in the entraining fluid of a separator, moving past an object in the fluid, which impinge on the object.

3.14 Terminal Velocity or Drop-Out Velocity

The velocity at which a particle or droplet will fall under the action of gravity, when drag force just balances gravitational force and the particle (or droplet) continues to fall at constant velocity.

3.15 Vapor Space

The volume of a vapor liquid separator above the liquid level.

4. SYMBOLS AND ABBREVIATIONS

The following is the list of symbols and abbreviations of parameters used in this Standard and their units of measurement:

A	= Cross-sectional area for gas flow, in (m^2).
a	= Length of side, square cyclone inlet, (type 1), in (m).
C	= Drag coefficient of particle or droplet, (dimensionless).
D_f	= Filter element outside diameter, in (m).
D_p	= Droplet or particle diameter, in (m).
D_v	= Internal diameter of a separator vessel, in (m).
d_n	= Nozzle diameter, in (m).
d_1	= Internal diameter of feed inlet, in (m).
d_2	= Internal diameter of gas outlet, in (m).
d_3	= Diameter of cylindrical cyclone baffle, in (m).
g	= Local acceleration due to gravity, in (m/s^2).
H	= Height, (tangent to tangent) of vessel, in (m).
H_c	= Height of cyclone (from bottom plate to outlet pipe), in (m).
h	= Height of vessel required for hold-up, in (m).
K	= Empirical constant for separator sizing, in (m/s).
K_{CR}	= Proportionality constant.
LA (L)	= Level Alarm (Low)
LA (H)	= Level Alarm (High)
L_f	= Filter element length, in (m).
L_v	= Length of a horizontal separator vessel, (tangent to tangent), in (m).
M_g	= Mass flow rate of gas, in (kg/s).
M_l	= Mass flow rate of liquid, in (kg/s).
P_{in}	= Pressure at inlet, in (kPa).
P_{out}	= Pressure at outlet, in (kPa).
Q	= Volumetric load factor, in (m^3/s).

Q_g = Volumetric flow rate of gas, in (m³/s).

Q_l = Volumetric flow rate of liquid, in (m³/s).

Q_{max} = Maximum value of Q, in (m³/s).

R = Radius of cyclone scroll f, in (m).

R_e = Reynolds number, (dimensionless).

s = Width of split between cyclone bottom plate and wall, in (m).

T = Time, in minutes (min).

t = Thickness of demister pad, in (m).

V_c = Critical gas velocity necessary for particles to drop or settle, in (m/s).

$V_{g,in}$ = Gas velocity at inlet, (superficial), in (m/s).

$V_{g,out}$ = Gas velocity at outlet, in (m/s).

V_m = Mixture velocity at inlet = $(Q_g + Q_l)/(\pi d_n^2/4)$, in (m/s).

V_t = Terminal or free settling velocity of particle or droplet and terminal rising velocity of bubbles, in liquid phase, in (m/s).

Greek Letters:

γ_l (gamma) = Liquid kinematic viscosity, in (mm²/s) or (cSt)

μ (mu) = Dynamic viscosity of continuous phase,in cP, (mPa.s).

μ_g (mu) = Dynamic viscosity of gas, in cP, (mPa.s).

ρ_g (rho) = Gas phase density, in (kg/m³).

ρ_l (rho) = Liquid phase density, in (kg/m³).

ρ_m (rho) = Mixture density at inlet = $(M_g+M_l)/(Q_g+Q)$, in(kg/m³).

5. UNITS

This Standard is based on International System of Units, (SI) as per IPS-E-GN-100 except where otherwise specified.

6. GENERAL

Gas-Liquid Separators can be generally divided into two main groups, high gas to liquid ratio (e.g. flare knock-out drums, scrubbers), and low gas to liquid ratio (e.g. oil/gas separators, flash tanks) separators. In this Standard, process aspects of three types of most frequently used gas (vapor)-liquid separators are discussed more or less in details, these three types are:

-Conventional gas-liquid separators (including oil/gas separators).

- Centrifugal gas-liquid separators.

- Gas-liquid filter separators.

Another frequently used type i.e., flare knock-out drum, is mentioned briefly since this type is discussed in details in IPS-E-PR-460 Standard, "Process Design of Flare and Blowdown Systems".

Types of mechanical separators are generally shown in Fig. F.1 of Appendix F.

6.1 Gas-Liquid Separators

Gas-liquid separator types often used in processes which are discussed in this Standard are:

- Conventional Gas/Liquid Separators.
- Cyclones.
- Oil/Gas Separators.
- Flare Knock-out Drums.
- Filter Separators.

6.2 Separation Mechanisms

Gas-liquid separation processes most frequently employed in industries are based on either one or a combination of "Gravity Settling", "Impingement" and "Centrifugation", mechanisms. Some types of "Filtration" are seldom employed in this field. The principles of mechanical separation in general, can be classified as momentum, gravity and filtration that are briefly are briefly described in the following sections. Note that as a general rule, mechanical separation occurs only when the phases are immiscible and have different densities.

6.2.1 Mechanical separation by momentum

Fluid phases with different densities will have different momentum. If a two phase stream changes direction sharply, greater momentum will not allow the particles of heavier phase to turn as rapidly as the lighter fluid, so separation occurs. Momentum is usually employed for bulk separation of the two phases in a stream.

6.2.2 Mechanical separation by gravity

Liquid droplets or solid particles will settle out of a gas phase if the gravitational force acting on the droplet or particle is greater than the drag force of the gas flowing around the droplet or particle. The same phenomenon happens for solid particles in liquid phase and immiscible sphere of a liquid immersed in another liquid. Rising of a light bubble of liquid or gas in a liquid phase also follows the same rules, i.e. results from the action of gravitational force. Regarding gravity settling, an overall picture of the range and distribution of particle sizes as well as the significant laws governing the particle settling in each range are shown in Fig. A.1 of Appendix A.

6.2.3 Mechanical separation by filtration

Filtration is the separation of a fluid-solid or liquid-gas mixture involving passage of most of the fluid through a porous barrier which retains most of the solid or liquid particulates contained in the mixture.

Filtration processes can be divided into three broad categories, cake filtration, depth filtration, and surface filtration.

6.3 General Notes on Separator Piping

Piping to and from the separator shall interfere as little as possible with the good working of the separator. The following constraints should be observed:

a) There should be no valves, pipe expansions or contractions within 10 pipe diameters of the inlet nozzle.

b) There should be no bends within 10 pipe diameters of the inlet nozzle. except the following:

- For knock-out drums and demisters, a bend in the feed pipe is permitted if this is in a vertical plane through the axis of the feed nozzle.
- For cyclones a bend in the feed pipe is permitted if this is in a horizontal plane and the curvature is in the same direction as the cyclone vortex.

c) If desired, a pipe reducer may be used in the vapor line leading from the separator, but it should be no nearer to the top of the vessel than twice the outlet pipe diameter.

If these conditions cannot be complied with, some loss of efficiency will result.

If a valve in the feed line near to the separator cannot be avoided, it should preferably be of the gate or ball type fully open in normal operation. High pressure drops which cause flashing and atomization should be avoided in the feed pipe. If a pressure-reducing valve in the feed pipe cannot be avoided, it should be located as far upstream of the vessel as practicable.

7. CONVENTIONAL GAS/LIQUID SEPARATORS

7.1 General

Conventional gas/liquid separators are usually characterized as vertical, horizontal, or spherical. Horizontal separators can be single or double barrel and can be equipped with sumps or boots.

Mist extractor can be installed in this type of separators.

7.1.1 Vertical separators

Vertical separators (see Fig. B.1-a of Appendix B) shall be selected when the gas-liquid ratio is high. In cases where there is a frequent fluctuation in inlet liquid flow or where re-vaporization or remixing of fluids in the vessel should be prevented, vertical separators should be preferred.

7.1.2 Horizontal separators

Horizontal separators (see Fig. B.1-b) are practically used where large volumes of total fluids and large amount of dissolved gas are present with the liquid. They are also preferred where the vapor-liquid ratio is small or where three phase separation is required.

7.1.3 Spherical separators

These separators are occasionally used for high pressure service where compact size is desired and liquid volumes are small, (see Fig. B.1-c).

7.2 Design Criteria

Separators without mist extractors may be designed for gravity settling using Stokes' law equations.

Typically the sizing is based upon removal of 150 micrometers and larger diameter droplets.

For practical purposes, to be in safe side, use of the methods presented in the following sections is recommended.

7.2.1 Design flow rates

A separator may be incorporated in a process scheme for which there are different modes of operation. In this case, the separator design shall be based upon the operation mode with the severest conditions. For the gas/liquid separation in a knock-out drum or demister, the severest condition is that with the highest value of Q, where this is defined by: EMBED Equation

$$Q = Q_g \left(\frac{\rho_g}{\rho_1 - \rho_g} \right)^{1/2} m^3/s \quad \textbf{(Eq.1)}$$

Having identified the severest mode from the highest value of Q, it is then necessary to add on a margin to give the value on which the separator design shall be based. This value, Q_{max} should include margins for over design, safety or surging. It represents the ’flooding’ condition.

The margin to be applied over the normal (process design) flow rate depends on the application. For oil processing, a margin of 15-25% is common; for oil production, margins up to 50% may be required.

7.2.2 Nature of the feed

The type of flow in feed pipe to the separator, transition from one flow regime to another, formation of droplets, foaming tendency of the liquid which may lead to carry over the liquid or carry through of gas and other factors such as existence of sands, rust, wax and other solids and cocking tendency of the liquid are points which should be Taken into account when fixing design conditions.

7.2.3 Efficiency and separator type

The efficiency of a separator is defined here as the fraction (or percentage) of the liquid entering the vessel that is separated off.

Table 1 gives the preferred choice of separator according to feed description and the approximate efficiency expected:

TABLE 1 - EFFICIENCY VS TYPE OF FLOW OF SEPARATORS

TYPE OF FLOW	EFFICIENCY EXPECTED	
	<90%	>90%
Bubbly	Knock-Out drum	
Stratified, smooth		Knock-Out drum
Stratified, wavy	Knock-Out drum	Demister or cyclone
Intermittent	Knock-Out drum	Demister or cyclone
Annular		Demister or cyclone

Although a demister separator fitted with wire mesh demister pad will often have efficiency better than 99%, it should be noted that a substantial fraction of droplets less than 20 micrometers in diameter, may pass through a wire mesh demister.

7.2.4 Liquid handling requirements

In checking the capacity of the separator to handle liquid, the following points should be considered.

7.2.4.1 Degassing

In order to prevent carry through of the gas bubbles into the liquid outlet stream in vertical vessels, the liquid velocity should satisfy the following requirement: EMBED Equation

$$\frac{Q_g}{\frac{\pi}{4} D_V{}^2} \langle \frac{2.18 \times 10^{-2}}{\gamma_1} \times \frac{\rho_1 - \rho_g}{\rho_1} \qquad \textbf{(Eq.2)}$$

Where γ_l, the liquid kinematic viscosity is in mm²/s or cSt.

In a horizontal vessel which is approximately half full, the above limit should be applied to the velocity $Q_l / (D_v . L_v)$, where L_v is the vessel length.

Note:

Often ’liquid residence time’ is used as a criterion for de-gassing. The method given here, based on Stokes’ law is preferred.

7.2.4.2 Control volume

For de-gassing (and also to counter foam), the liquid velocity should be limited. When a liquid level is required in the separator, a certain liquid volume is necessary for control purposes.

The following recommendations are intended as a guide:

a) Hold-Up time for control

The minimum requirement between LA(L) and LA(H) shown in Fig. G.1 of Appendix G, which should be applied in the absence of other overriding process considerations, is as follows:

Automatic control

4 minutes for product to storage

5 minutes for feed to a furnace

4 minutes for other applications

Manual control

20 minutes.

b) Hold-Up time for operator intervention

When operator action is necessary to avoid upsets or a shutdown of plant operation, a realistic estimate shall be made of the time required.

For inside plot separators a minimum hold-up of 5 minutes between pre-alarm and trip action is recommended.

For off plot separators, the time the operator needs to reach the equipment, should be added.

No hold-up is required for switches which do not directly affect plant operation, e.g., automatic starting of standby pump. The pre-alarm may then be omitted.

7.2.4.3 Liquid slugs

If the feed contains slugs of liquid, extra hold-up volume is required. In the absence of other information, the slug volume should be taken as 2-5 seconds of flow with the normal feed velocity and 100% liquid filling of the feed pipe.

The separator should be able to accommodate this slug volume between NL and LA (H) or between NL and LA (HH), depending on whether it is required for the arrival of a slug to sound the high-level alarm, or not. To increase the volume for accommodation of the slug the NL may be set closer to LA (L). (For an explanation of liquid level control terms, see Fig. G.1 of Appendix G.)

Note:

When slugs are expected in the feed, consideration should be given to strengthening the piping and feed inlet device, if one is to be fitted.

7.2.5 Separator design methods

Recommended methods for basic (process) design of conventional Gas-Liquid Separators are presented in the following sections. Although general references are available in literature. For symbols and abbreviations see Section 4.

7.2.5.1 Conventional separators without mist extractors

This type of separator vessel utilize gravity as the main mechanism for separating the liquid and gas phases.

To design a separator without a mist extractor, the minimum size diameter droplet to be removed must be set. Typically this diameter is in the range of 150 to 2000 micrometers. Although the calculation method for gravity settling is valid for this type, the methods given in the following sections can also yield to a safe basic design.

7.2.5.1.1 Vertical knock-out drum without mist extractors

a) Diameter

The vessel diameter, D_v, can be estimated from: EMBED Equation

$$\frac{Q_{max}}{\pi / 4.D_v^{\,2}} \leq 0.07 \qquad \textbf{(Eq. 3)}$$

Where:

Q_{max} is the process design value of Q plus margin (see 7.2.1).

b) Height

If h is the height of vessel required for liquid hold-up (see 7.2.4.2), then the total vessel height (tangent to tangent) is

$$H = h + d_n + X + Y \qquad \textbf{(Eq. 4)}$$

Where:

d_n is Inlet nozzle diameter, in m;

X is 0.3 D_v with a minimum of 0.3 m;

Y is 0.9 D_v with a minimum of 0.9 m.

c) Nozzles

1) Feed Nozzle

The feed nozzle shall be fitted with a half open pipe or a flow diverting box inlet device. The nozzle diameter, d_n, may be taken equal to that of the feed pipe but the product $\rho_m \times V^2_m$ shall not exceed 1500 kg/m.s².

2) Gas Outlet Nozzle

The diameter of the gas outlet nozzle should normally be taken equal to that of the outlet pipe, but the product $\rho_g \times V_g^2$,out shall not exceed 3750 kg/m.s².

3) Liquid Outlet Nozzle

The diameter of the liquid outlet nozzle shall be choosen such that the velocity in it does not exceed 1 m/s, but should preferably be lower. The nozzle shall be equipped with a vortex breaker.

d) Pressure Drop

The pressure differential between inlet and vapor outlet is:

$$P_{in} - P_{out} = 8 \times 10^{-4} \times \rho_g \times V2_{g,out}\ kPa \qquad \text{(Eq. 5)}$$

7.2.5.1.2 Horizontal knock-out drum without mist extractor

For a horizontal knock-out drum, the following design method can be applied:

a) Size

The cross-sectional area for gas flow, A, follows from:

$$\frac{Q_{max}}{A} \leq 0.1\ m/s \qquad \text{(Eq. 6)}$$

Where A is taken above the LA (HH) liquid level and Q_{max} is the process design value of Q plus a margin, see(7.2.1). Horizontal vessels are usually designed to be between about one third and one half-full of liquid.

Note:

The liquid hold-up volume is determined by other considerations, See (7.2.4). The design method involves trial and error. L_v and D_v are fixed, and a fractional filling chosen to satisfy liquid hold-up requirements. It is then necessary to check that Q_{max}/A does not exceed 0.1 m/s. A starting value for the ratio L_v/D_v of 3.0 is suggested; values of 2.5 to 6.0 for this ratio are normal; values of 6.0 or higher are recommended for high-pressure applications.

b) Nozzles

1) Feed Nozzle

The nozzle diameter, d_n, may be taken equal to that of the feed pipe, but the product

$$\rho_m \times V^2_m \qquad \text{(Eq. 7)}$$

shall not exceed 1000 kg/m.s².

2) Gas Outlet Nozzle

For gas outlet nozzle, the same method can be applied as for a vertical vessel, (see 7.2.5.1.1).

3) Liquid Outlet Nozzle

For Liquid outlet nozzle, the same method can be applied as for a vertical vessel, (see 7.2.5.1.1).

c) Pressure Drop

The pressure drop can be calculated as for a vertical vessel (see 7.2.5.1.1).

7.2.5.2 Conventional gas-liquid separators with wire mesh mist extractors

Wire mesh pads are frequently used as entrainment separators for the removal of very small liquid droplets and, therefore, a higher over-all percentage removal of liquid. Removal of droplets down to 10 micrometers or smaller may be possible with these pads. Typical wire mesh installation in gas-liquid separators is illustrated in Fig. B.1 of Appendix B.

In plants where fouling or hydrate formation is possible or expected, mesh pads are typically not used. In these services vane or centrifugal type separators are generally more appropriate.

Most installations will use a 150 mm thick pad with 145-190 kg/m³ bulk density. Minimum recommended pad thickness is 100 mm. Manufacturers should be contacted for specific designs.

If the mist eliminators need to be designed for an excessively large size, the vessels shall be designed for a horizontal type.

7.2.5.2.1 Vertical demister separators

Most vertical separators that employ mist extractors are sized using equations that are derived from gravity settling equations . The most common equation used is the critical velocity equation:

$$V_c = K\sqrt{\frac{\rho_1 - \rho_g}{\rho_g}} \qquad \textbf{(Eq. 8)}$$

Some typical values of the separator sizing factor, K, are given in Table 2. Note that this equation actually gives the size of the separation element (mist extractor), and does not size the actual separator containment vessel. That means the vessel may be selected larger than the element, (e.g., for surge requirements).

The following is a rough, but safe sizing method for vertical demister separators:

a) Diameter

The vessel diameter, Dv follows from:

$$\frac{\mathrm{Q}_{\max}}{\pi / 4D_v^2} \leq 0.105 m/s \qquad \textbf{(Eq. 9)}$$

When a standard support ring for the demister mat is designed, then the width of the ring is considered to be negligible and D_v calculated from the above formula will be the vessel internal diameter.

Notes:

1) For viscous liquids, the maximum capacity of a horizontal demister mat is less.

For μg =100 cP reduce the value 0.105 m/s by 10%.

For μg =1000 cP, apply 20% reduction.

2) Maximum capacity of the mat decreases as the rate of liquid fed to it increases. The above values apply to a lightly loaded mat, as encountered in most separators.

b) Height

Let h be the height of vessel required for liquid hold-up (see 7.2.4.2). Then the total vessel height (tangent to tangent)is

$$H = h + d_n + t + X + Y + 0.15\ D_v \qquad \text{(Eq. 10)}$$

Where:

d_n = diameter of inlet nozzle

t = thickness of demister mat, usually 0.1 m

X = 0.3 D_v with a minimum of 0.3 m
Y = 0.45 D_v with a minimum of 0.9 m
} for a vessel equipped with half-open pipe inlet device

c) Nozzles

1) Feed nozzle

When the vessel diameter is less than 0.8 m the feed nozzle should be fitted with a half-open pipe inlet device. The rule for sizing is as given under (7.2.5.1.1 c).

For vessel diameters of 0.8 m and greater, a vane-type inlet device is recommended. The diameter of the nozzle d_n, may be taken equal to that of the feed pipe, but the following two criteria shall also be satisfied:

$$\rho_m . V^2 \leq 6000\ kg / m.s^2 \qquad \text{(Eq. 11)}$$

$$\rho_g . V^2_{g,in} \leq 3750\ kg / m.s^2 \qquad \text{(Eq. 12)}$$

Where:

$$\rho_m = (M_g + M_l)/(Q_g + Q_l), \qquad \text{(Eq. 13)}$$

mean density of mixture in the feed pipe,

and,

$$V_m = (Q_g + Q_1) / \frac{\pi}{4} d_1^{\,2}, \qquad \text{(Eq. 14)}$$

velocity of mixture in the inlet nozzle.

A typical vane type inlet device is shown in Appendix "C".

2) Gas Outlet Nozzle

For gas outlet nozzle, the same method may be applied as for a vertical knock-out drum (without mist extractor) (see 7.2.5.1.1).

3) Liquid Outlet Nozzle

Same as 2 above.

d) Pressure drop

In addition to the pressure drop given in (7.2.5.1.1.d), it is sufficient for most purposes to assume that the extra pressure drop over the demister mat is equivalent to 10 mm of liquid.

The vane type inlet does not cause any significant pressure drop.

e) Demister mat specifications

The mat shall be made of knitted wire formed to give the correct shape, and not cut so as to leave raw edges and loose pieces of wire which could become detached.

The wire mesh shall have a free volume > 97%, a wire surface area > 350 m^2/m^3 and a wire thickness $\geq$ 0.23 mm and $\leq$ 0.28 mm.

The thickness of 0.1 m for the mat is recommended. The wire mat shall be placed between two grids and shall be fastened in such a way that it cannot be compressed when being mounted.

TABLE 2 - TYPICAL K FACTORS FOR SIZING WIRE MESH DEMISTERS

SEPARATOR TYPE	K. FACTOR m/s
Horizontal (with vert. pad)	0.122 to 0.152
Spherical	0.061 to 0.107
Vertical or horizontal (with horiz. pad)	0.055 to 0.107
At atm. press.	0.107
At 2100 kPa	0.101
At 4100 kPa	0.091
At 6200 kPa	0.082
At 10300 kPa	0.064
Wet steam	0.076
Most vapors under vacuum	0.061
Salt and caustic evaporators	0.046

Notes:

1) K = 0.107 at 700 kPa - Subtract 0.003 for every 700 kPa above 700 kPa.

2) For glycol and amine solutions, multiply K by 0.6 to 0.8.

3) Typically use one-half of the above K values for approximate sizing of vertical separators without wire mesh demisters.

4)For compressor suction scrubbers and expander inlet separators multiply K by 0.7 - 0.8.

7.2.5.2.2 Horizontal demister separators

Horizontal separators with mist extractors are sized using the equation presented in 7.2.5.2.1 except that a factor is added for the length, L_v, of the gas flow path.

Separators can be any length, but the ratio of seam-to-seam length to the diameter of the vessel, L_v/D_v, is usually in the range of 2:1 to 4:1,

$$V_c = K\sqrt{\frac{\rho_1 - \rho_g}{\rho_g}}\left(\frac{L_V}{10}\right)^{0.56} \qquad \textbf{(Eq. 15)}$$

K values given in Table 2 can be used for horizontal demister separators.

Note that the preferred orientation of mesh pad in horizontal separators is in the horizontal plane, and it is reported to be less efficient when installed in vertical position. But both designs are actually used due to specified applications.

The method presented in the following sections can be followed as a quick and safe method for basic design of horizontal demister separators.

a) Size

1) Horizontal Mat

For sizing a horizontal separator with a horizontal mat, the equation and method presented above in this section is recommended.

2) Vertical Mat

For a horizontal vessel fitted with a vertical mat, as shown in Fig. G.2 of Appendix G, the equation bellow can be applied:

$$\frac{Q_{max}}{A} \leq \mathbf{0.15\ m/s} \qquad \textbf{(Eq. 16)}$$

Where: A is taken above the LZA (HH) liquid level and Q_{max} is the process design value of Q plus a margin, (see 7.2.1). Horizontal vessels are usually designed to be between about one third and one half-full of liquid.

b) Nozzles

1) Feed nozzle, dn1

The feed nozzle shall be fitted with a vane-type or another type of inlet device. The diameter of the nozzle,d_{n1}, may be taken equal to that of the feed pipe but the following two criteria shall also be satisfied:

$$\rho_m . V^2 \leq 6000\ kg / m.s^2 \qquad \textbf{(Eq. 17)}$$

$$\rho_g . V^2_{g,in} \leq 3750\ kg / m.s^2 \qquad \textbf{(Eq. 18)}$$

The length of the vane type inlet nozzle should be taken equal to approximately 5 times the feed nozzle diameter.

A Typical Vane type inlet device is shown in Appendix C.

2) Gas Outlet Nozzle, d_{n2}

For the gas outlet nozzle, the same method applies as for a vertical knock-out drum, (see 7.2.5.1.1).

3) Liquid Outlet nozzle, d_{n3}

For the liquid outlet nozzle, the same method applies as for a vertical knock-out drum, (see 7.2.5.1.1).

c) Pressure Drop

In addition to the pressure drop given in (7.2.5.1.1-d), it should be sufficient for most purposes to assume that the extra pressure drop over the demister is equivalent to 10 mm of liquid. There will be no additional pressure loss over the vane type inlet device.

d) Demister mat specifications

General specifications shall be as given under (7.2.5.2.1-e). However, it is recommended that for a vertical mat of height greater than 1.5 m (from NL to top) the thickness should be increased to 0.15 m.

e) Boots

Boots, if necessary, shall be sized for a minimum residence time of five minutes as a guideline, their diameters shall be the same as the commercial pipe sizes as far as possible.

The height-diameter ratio shall be 2:1 to 5:1, it shall be determined with consideration given to operability and the minimum sizes of level instruments and equipment.

Boot diameters shall be 300 mm minimum because good operability cannot be provided if the boots are smaller than 300 mm.

Maximum boot diameters shall be 1/3 of the drum inside diameter.

7.2.5.3 Separators with vane type mist extractors

Vanes differ from wire mesh in that they do not drain the separated liquid back through the rising gas stream. Rather, the liquid can be routed into a downcomer, which carries the fluid directly to the liquid reservoir. A vertical separator with a typical vane mist extractor is shown in Fig. D.1 of Appendix D.

The vanes remove fluid from the gas stream by directing the flow through a torturous path. A cross-section of a typical vane unit is shown in Fig D.2 of Appendix D.

Vane type separators generally are considered to achieve the same separation performance as wire mesh, with the added advantage that they do not readily plug and can often be housed in smaller vessels. Vane type separator designs are proprietary and are not easily designed with standard equations. Manufacturers of vane-type separators should be consulted for detailed designs of their specific equipment.

7.3 Specification Sheet

The following process points should be considered when preparing a specification sheet (or process data sheet) for a gas/liquid separator (see also Appendix E of API Specification 12J). For mechanical specification sheet, reference should be made to IPS-G-ME-150.

1) Application Service:

a) Source of Entrainment.

b) Operating Conditions (Normal, minimum, maximum):

- Temperature;
- Pressure;
- Vapor Phase:

  Flow Rate.

  Velocity.

  Density (at operating conditions).

  Molecular Mass.

  Composition or Nature of Phase.

- Liquid Entrainment Phase:

  Quantity (if known).

  Density.

  Viscosity.

  Surface Tension.

  Composition or Nature of Entrainment.

Droplet Sizes or Distribution (if known).

Solids Content (composition and quantity):

- Dissolved.
- Suspended.

c) Performance

- Allowable Total Separator Pressure Drop.
- Allowable Mesh Pressure Drop.
- Allowable Entrainment.
- Mesh Thickness Recommended.
- Mesh Type

2) Construction and Installation:

a) Vessel

- Diameter (ID), and Length.
- Position (Horizontal, Vertical, Inclined).
- Shape (Circular, Square, etc.).
- Type (Evaporator, Still, Drum, etc.).

3) Material of construction (Material Group)

4) Special Conditions

7.4 Oil/Gas Separators

7.4.1 General

Oil/gas separators are a certain group of gas/liquid separators which are specially used in oil and/or gas fields, in order to separate gas, crude and water from a well stream. Oil/gas separators can be made vertical, horizontal and spherical, but the most common type used is horizontal. In sizing oil/gas separators, API, Spec. 12J, "Specification for Oil Gas Separators", should be used as the main reference. Some special considerations are also presented in the following sections

7.4.2 Additions to API Spec. 12J

In addition to API Spec. 12J, the following points are also recommended in design and selection of oil/gas separators (see Fig. 1).

7.4.2.1 Mist eliminator type and installation point

a) Type

Dependent on the quality of the crude, either wire mesh or vane type eliminators could be used. However, the use of the vane type is usually preferred due to non plugging aspect. This becomes a must if waxy crudes are encountered.

b) Installation Point

After entering the separator, the associated gas travels in a longitudinal plane along the top half of the separator. Therefore it is recommended that the gas outlet mist eliminator be placed at the furthest point away from the inlet diverter. This allows the gas maximum residence time in the vessel to ensure that the majority of the liquid droplets entrained in the gas are released prior to the gas outlet from the vessel.

7.4.2.2 Inlet Diverter

An inlet diverter should always be included as this will break up the bulk of the inlet stream into smaller particles.

There are various types available all of which are used by manufacturers. These types are listed below:

a) The dished end type inlet diverter directs the inlet fluid back into the vessel head. This is used in cases where the inlet nozzle is in the head of the vessel.

b) The fluid is directed back against the vessel head by a 90 degree elbowed pipe. This type is used for gases.

c) Presently the most common of all types is either a vane, angle or pipe type inlet diverter in a box type arrangement.

7.4.2.3 Coalescing packs

Coalescing packs (or pads) have special designs and are used by some manufacturers (in three-phase separators) in order to assist the separation of liquid phases. These are usually installed in the oil layer, however in certain instances where produced water clean up is important, the pack can be installed across both layers.

7.4.2.4 Operating levels

As a general rule maximum operating level in a horizontal crude oil separator should not exceed 50%, and minimum level should not be less than 200 mm.

In certain circumstances however, the maximum level can be raised to 60%, i.e., if gas/oil ratio is particularly low or if in conjunction with a relatively low gas rate the required liquid removal efficiency from the gas can be relaxed.

The minimum liquid level of 200 mm from the bottom inside of the shell cannot practically be reduced, as it would be very difficult to control, in most cases this would be the low level shut-down position.

Alarm/shut-down positions are usually specified by engineering Judgment, but the following general rules for high and low levels based on previous operating experience, are recommended:

a) The high liquid level shut-down positions should not be greater than 70% in any circumstances, and in addition it should not be more than 100 mm lower than the inlet nozzle.

b) The low liquid level shut-down position cannot be less than 200 mm above the bottom inside wall of the separator shell due to practical control installation problems.

7.4.2.5 Vortex breakers

Vortex breakers should always be installed on liquid outlet nozzle (2 phase), or water and oil nozzle in the case of 3 phase separators.

7.4.2.6 Three-Phase vessel weir plates

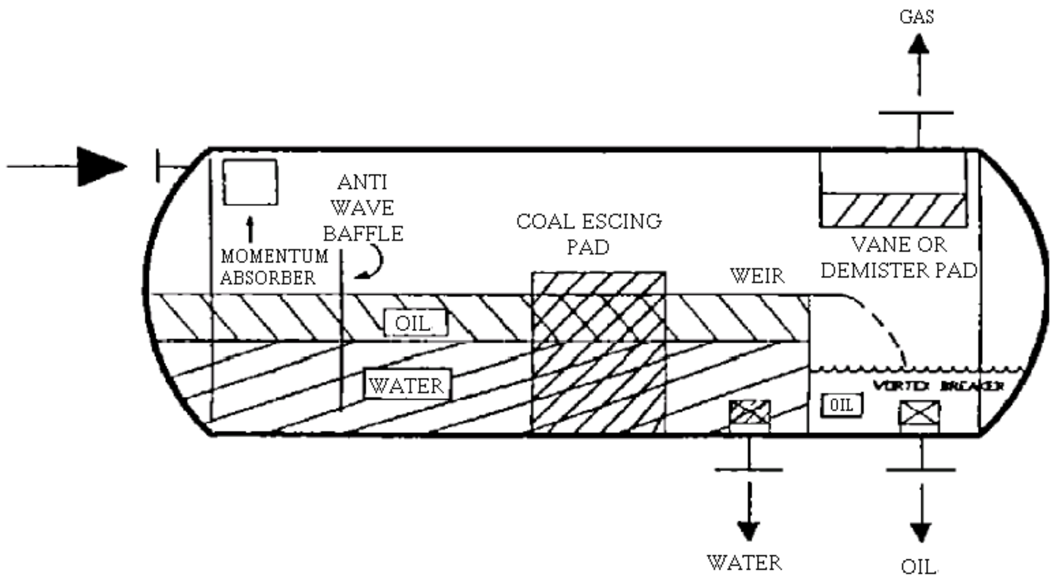
The weir plate is a device which separates oil and water into two compartments.

Weir plates can be either fixed or adjustable. Fixed weir plates should be used in cases where the water content is constant. Adjustable weir plates are required when the water content is expected to increase.

Generally, the weir plate should always be 150 mm (minimum) above the oil/water interface. It can vary in height from the bottom inside shell wall to the top of the plate from 300 mm to the mid point of the vessel.

7.4.2.7 Anti wave baffles

In large volume 3 phase separators it is sometimes necessary to install an anti wave baffle(s) to eliminate disturbances of oil/water interface. This is a partial cross sectional area plate with punched holes which act as a wave breaker while still letting liquid pass through (see Fig. 1).



A TYPICAL HORIZONTAL OIL/GAS/WATER SEPARATOR

Fig. 1

8. CENTRIFUGAL GAS/LIQUID SEPARATORS

8.1 General

Centrifugal separators utilize centrifugal action for the separation of materials of different densities and phases. They are built in stationary and rotary types. Various modifications of stationary units are used more than any other kind. Centrifugal separators are generally divided into three types:

1) Stationary Vane Separators.

2) Cyclone Separators.

3) Inertial Centrifugal Separators.

The efficiency of each of three types can be estimated using Table 3. Because of wide usage of cyclone separators for separation of liquid entrainment from gas streams, this type is discussed in the following sections.

TABLE 3 – EFFICIENCY OF GAS/LIQUID SEPARATORS

TYPE	EFFICIENCY RANGE
High velocity stationary vanes	99% or higher of entering liquid. Residual entrainment 1 mg/kg (ppm) or less.
Cyclone separator	70-85% for 10 micrometers, 99% for 40 micrometers, and larger. For high entrainment, efficiency increases with concentration.
Rotary	98% for agglomerating particles

8.2 Cyclone Separators

8.2.1 General

The cyclone type unit is well recognized and accepted in a wide variety of applications from steam condensate to dusts from kilns. In this unit the carrier gas and suspended particles enter tangentially or volutely into a cylindrical or conical body section of the unit, then spiral downward forcing the heavier suspended matter against the walls.

Solids tend to slide down the wall while liquid particles wet the wall, form a running film and are removed at the bottom.

Units shown in Fig. E.1 of Appendix E, have been used in many process applications specially in liquid entrainment separation, with a variety of modifications.

8.2.2 Design Criteria

The design incorporates two special internals, the bottom plate with vortex spoilers, and the cylindrical baffle at the top of the cyclone.

8.2.2.1 Diameter

The diameter of the cyclone should be related to the size of the inlet, as follows:

TYPE I

$$a = 7\times10^{-5}\left[\frac{Q_g.(\rho_1-\rho_g)}{\mu_g}\right]^{1/3} \quad \textbf{(Eq. 19)}$$

$$a = 0.13\ \rho_g^{\ 1/4}.Q_g^{\ 1/2} \quad \textbf{(Eq. 20)}$$

"a", should be taken as the larger of the values calculated from the above two equations. The diameter is then given by:

$$D_v = 2.8\,a \quad \textbf{(Eq. 21)}$$

TYPE II

$$d_1 = 7\times10^{-5}\left[\frac{Q_g.(\rho_1-\rho_g)}{\mu_g}\right]^{1/3} \quad \textbf{(Eq. 22)}$$

$$d_1 = 0.15\ \rho_g^{\ 1/4}.Q_g^{\ 1/2} \quad \textbf{(Eq. 23)}$$

d_1, should be taken as the larger of the values calculated from the above two equations. The diameter is then given by:

$$D_v = 3.5\,d_1 \quad \textbf{(Eq. 24)}$$

Where:

a, D_v and d_1 **are, in meters;**

Q_g **is, in m³/s;**

ρ_1 ***and*** ρ_g **are, in kg/m³;**

μ_g **is, in cP (m Pa s).**

The superficial liquid velocity in the inlet nozzle should not exceed 1 m/s.

8.2.2.2 Height

The following applies to both Type I and II:

When $\frac{M_1}{M_g} \geq 1$ ***take*** $\frac{H_C}{D_V} = 0.5 \text{ to } 0.7$ **(Eq. 25)**

When $\frac{M_1}{M_g} = 1 \text{ to } 0.1$ ***take*** $\frac{H_C}{D_V}. = 0.7 \text{ to } 1.2$ **(Eq. 26)**

When $\frac{H_C}{D_V} = 0.1 \text{ to } 0.01$ ***take*** $\frac{H_C}{D_V} = 1.2 \text{ to } 1.7$ **(Eq. 27)**

When $\frac{H_C}{D_V} = 0.1 \text{ to } 0.001$ ***take*** $\frac{H_C}{D_V} = 1.7 \text{ to } 2.2$ **(Eq. 28)**

M_1 and M_g denote the mass flow rates of liquid and gas, respectively in kg/s.

The shape and size of the space below the bottom plate has no effect on the working of the cyclone and shall be determined in connection with liquid hold-up requirements (7.2.4.2). It is important that any liquid level shall always be kept below the bottom plate.

8.2.2.3 Nozzles

Flow area of the gas outlet should be taken to be equal to that of the inlet, as shown in Fig. E.1 of Appendix E.

The liquid drain shall be sized so that the velocity in it does not exceed 1 m/s but should preferably be lower. A vortex breaker shall be used as indicated in Appendix E.

8.2.2.4 Pressure drop

Pressure differentials between inlet, vapor outlet and liquid drain are as follows:

$$P_{in} - P_{out} = X.\ \rho_g.\ V^2_{g,in}\ kPa \qquad \textbf{(Eq. 29)}$$

$$P_{in} - P_{drain} = y.\ \rho_g.\ V^2_{g,in}\ kPa \qquad \textbf{(Eq. 30)}$$

Where:

ρ_g ***is in kg/m³ and Vg,in in m/s***

For Type I : X = 0.015 and Y = 0.005

For Type II : X = 0.10 and Y = 0.003

8.2.2.5 Liquid drain sealing

For satisfactory operation of any cyclone it is essential that the liquid drain will be sealed, i.e., there shall be no flow of vapors in either direction in the drain.

Liquid from the cyclone will sometimes be drained via a dip leg to a receiving vessel. In such cases it is essential that a pressure balance shall be calculated to ensure that the liquid level always remains below the bottom plate. If the level rises above this plate, severe entrainment will result.

8.2.2.6 Foaming service

For foaming systems the width of split between the bottom plate and the wall, s, should be increased such that

$$\frac{s}{D_V} = 0.05 \qquad \textbf{(Eq. 31)}$$

A minimum width of split of 20 mm is recommended in foaming service.

8.2.3 Multi-Cyclone separators

Scketch of a multi-cyclone separator is shown in Fig. E.2 of Appendix E. This type of centrifugal separator is a high efficiency one which is claimed by manufacturers to be capable of remove almost all liquid droplets of 5 micrometer diameter and larger. This type can also be used in gas-solid separation services.

8.2.4 Specification sheet

The following points should be considered when preparing a spec. sheet (or process data sheet) for a cyclone separator in liquid entrainment separation service.

1) Application: (service application of unit should be described if possible).

2) Fluid Stream.

3) Fluid Composition (vol%).

4) Entrained Particles:

- **a)** Size Range (micrometers or mesh).
- **b)** Size percentage distribution.
- **c)** True Relative Density (Specific Gravity) of Particle, referred to water = 1.0.
- **d)** Source of Entrainment, (boiling liquid, etc.).
- **e)** Composition.

5) Operating Conditions, (minimum, maximum and Normal):

- **a)** Gas Flow Rate.
- **b)** Entrained Flow Rate.
- **c)** Temperature, (°C).
- **d)** Pressure, (kPa).
- **e)** Moisture Content.
- **f)** Dew Point, (°C).

6) Installation Altitude:

- **a)** Normal Barometer, (mm Hg).

7) Nature of Entrained Liquid:

- **a)** Description, (Oily, Corosive, etc.).
- **b)** Surface Tension at Operating Conditions.
- **c)** Viscosity at Operating Conditions.

8) Insulation Required and Reason.

9) Construction Features:

- **a)** Storage Required for Collected Liquid, (hours).

b) Preliminary Size of the Inlet Connection: (mm).

10) Special Conditions (if any).

9. FLARE KNOCK-OUT DRUMS

9.1 General

Flare KO drums are one type of gas/liquid separators which are used specifically for separation of liquids carried with gas streams flowing to the flares in oil, gas and petrochemical (OGP) plants.

The main difference between Flare K.O drums and other conventional gas/liquid separators lies in the size of the droplets to be separated, i.e., separation of 300, 600 micron (µm) droplets, fulfills the requirements of flare gas disengagement. Therefore usage of mist eliminating device is not usually necessary in Flare K.O drums except for cases where the results of calculations lead to an abnormally large drum size. In such cases, application of vane type or multicyclone separators may help to avoid employing an extremely large drum.

9.2 Design Criteria

For detail sizing procedure, please refer to "Engineering Standard for Process Design of Flare and Blowdown Systems", IPS-E-PR-460.

10. GAS/LIQUID FILTER SEPARATORS

10.1 General

Gas/Liquid filter separator (usually called "gas filter separator"), is used in separation of liquid and solid particles from gas stream. Gas filter separator has a higher separation efficiency than the centrifugal separator, but it uses filter elements which must periodically be replaced. Gas filter separator cannot handle more than small quantities of liquid (greater than 30 to 170 liters per 1000 Standard m^3).

This type of separator is usually made horizontal with a lower liquid barrel (see Fig. 2), but vertical type, specially when space saving is important, is offered by manufacturers (see Fig. 3).

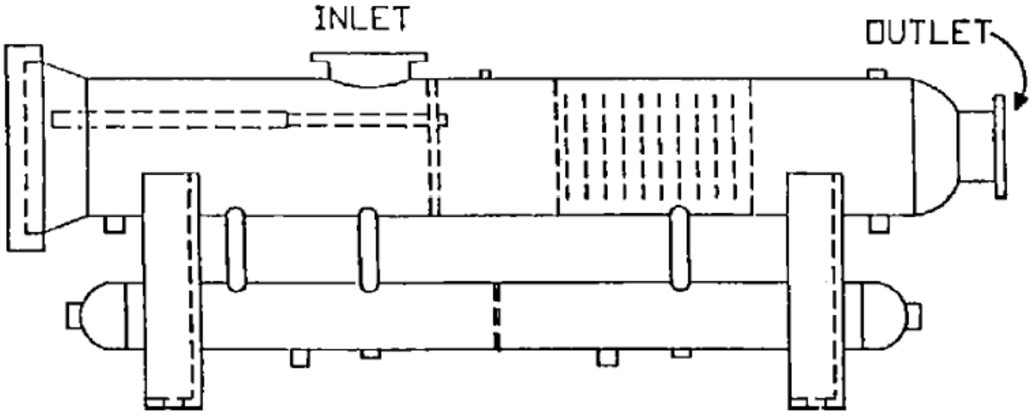
10.1.1 Applications

Typical applications of gas filter separators are as follows:

- Compressor stations to protect compressors from free liquid and prevent cylinder wear from solids.
- Metering and pressure reduction stations at city gates: to remove liquid hydrocarbons, water, sand and pipe scale.
- Protection of desiccant beds and collection of dust carry-over from beds.
- Gas storage systems: to prevent injection or withdrawal of solids, dust, and small amounts of liquids.
- Fuel lines to power plants and engines.
- Etc.

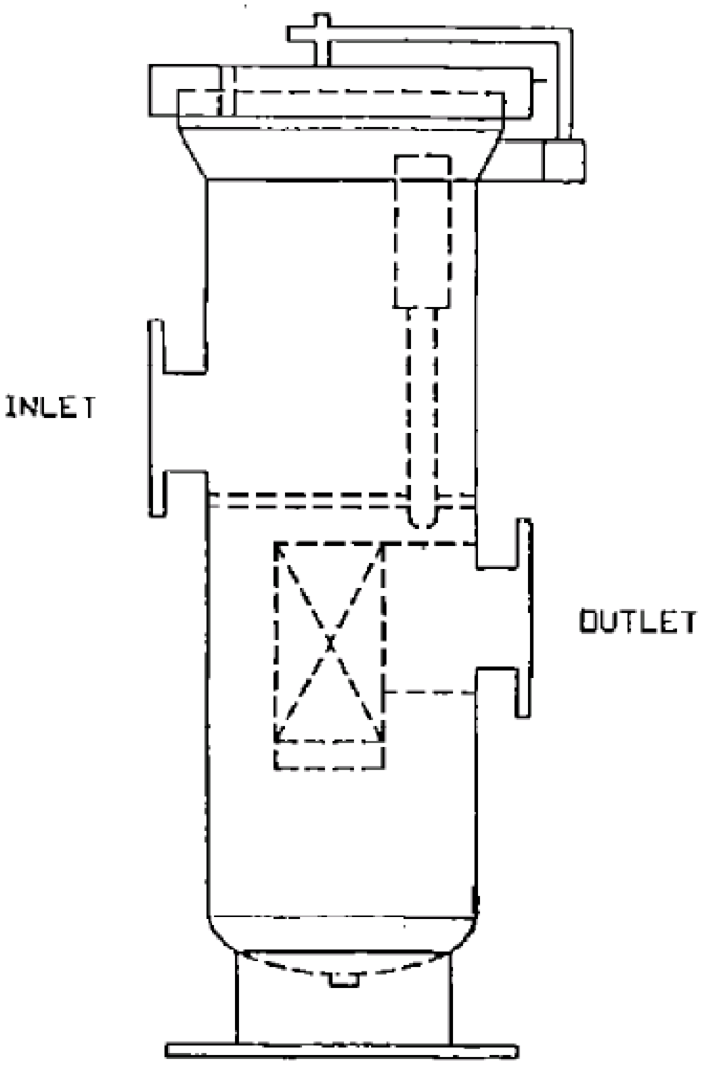
Note:

This type of separator shall not be used on a stream carrying wax or a congealing liquid, otherwise, filter elements will plug.



SKETCH OF HORIZONTAL GAS FILTER SEPARATOR

Fig. 2



SKETCH OF VERTICAL GAS FILTER SEPARATOR
Fig. 3

10.1.2 Operation

10.1.2.1 Operating principles

As it is shown in Fig. 2, gas enters the inlet nozzle and passes through the filter section where solid particles are filtered from the gas stream and liquid particles are coalesced into larger droplets. These droplets pass through the tube and are entrained into the second section of the separator, where a final mist extraction element removes these coalesced droplets from the gas stream.

10.1.2.2 Filter elements

The most common and efficient filter element (agglomorator) is composed of a fiber glass tubular filter pack which is capable of holding the liquid particles through submicron sizes.

10.1.2.3 Mist elimination

Mist elimination from gas stream is performed in the liquid compartment of the filter using a wire mesh or vane type mist extractor installed in the gas outlet. Rules presented in the previous sections of this Standard for demister gas/liquid separators govern here (see 7.2.5.2).

10.1.2.4 Liquid removal

For heavy liquid loads, or where free liquids are contained in the inlet stream, a horizontal filter separator with a liquid sump, which collects and dumps the inlet free-liquids is often preferred. In such cases, another sump drum for the separated liquid in the demister compartment should also be prepared.

When the liquid quantity is guaranteed to be small (less than 30 liters/1000 cm^3), there is an economic saving to be made by having a lower barrel in the demister or vane compartment only. If the liquid quantity is large, then it is required to dump liquid from the first compartment too.

Vertical vessels should only be used for the removal of solid particles with very small traces of liquid present.

10.1.3 Efficiency

The efficiency of a filter separator largely depends on the proper design of the filter pack, i.e., a minimum pressure drop while retaining an acceptable extraction efficiency.

Regarding the filtration capability, various guarantees are available from filter separator manufacturers, among them, ability of a filter to remove 100 percent of 8 micron and larger liquid droplets or solid particles, 99.5 percent of 3 micron and larger and 98 percent of droplets (or particles) larger than 1 micron is recommended to be specified.

However, note that guarantees for the performance of separators and filters are very difficult to verify in the field.

10.2 Design Criteria

The design of filter separators is proprietary and a manufacturer should be consulted for specific size and recommendations. However, the following points may be useful in basic process design stage.

10.2.1 Vessel size

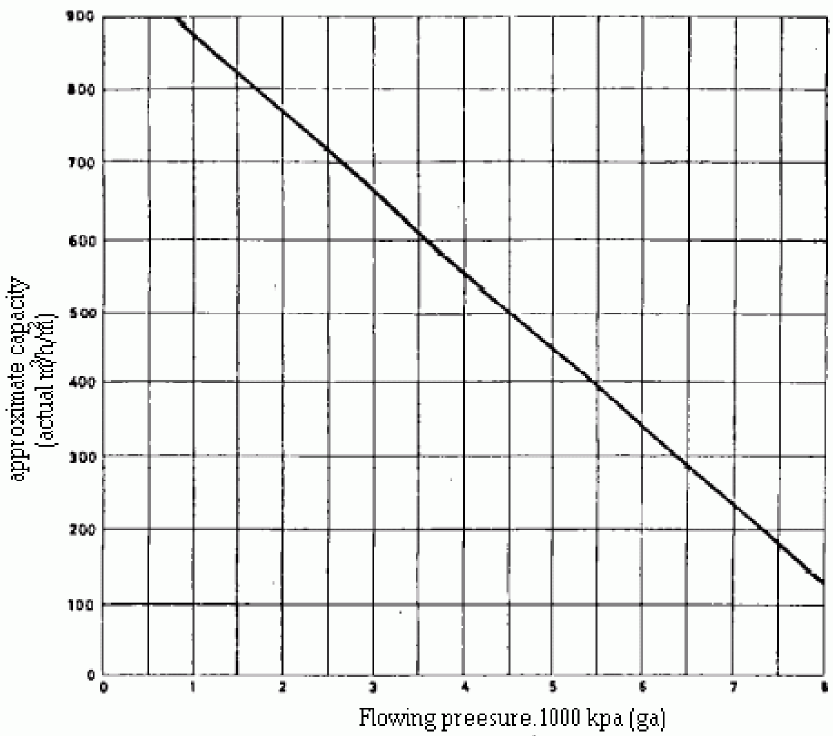
The body size of a horizontal filter separator for a typical application can be estimated by using 0.4 for the value of K in the equation of Section 7.2.5.2.1. This provides an approximate body diameter for a unit designed to remove water (other variables such as viscosity and surface tension enter into the actual size determination). Units designed for water will be smaller than units sized to remove light hydrocarbons.

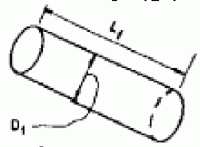
In many cases the vessel size will be determined by the filtration section rather than the mist extraction section.

10.2.2 Filter section

The filter cartridges coalesce the liquid mist into droplets which can be easily removed by the mist extractor section. A design consideration commonly overlooked is the velocity out of these filter tubes into the mist extraction section. If the velocity is too high, the droplets will be sheared back into a fine mist that will pass through the extractor element. No published data can be cited since this information is proprietary with each filter separator manufacturer.

The approximate filter surface area for gas filters can be estimated from Fig. 4. The figure is based on applications such as molecular sieve dehydrator outlet gas filters. For dirty gas service the estimated area should be increased by a factor of two or three.





Notes:
Area of a Filter Element is: π D_f L_f
Filter Surface Area is:
(No. of Elements) × π D_f L_f

Where D_f L_f are the Filter Element outside diameter and length respectively.

APPROXIMATE GAS FILTER CAPACITY
Fig. 4

10.2.3 Pressure drop

A pressure drop of 7-15 kPa is normal in a clean filter separator, but 7 kPa is often recommended to be specified in specification sheets. If Excessive solid and particles are present, it may be necessary to clean or replace the filters at regular intervals when a pressure drop in excess of 70 kPa is observed.

Although the filter coalescing elements are usually designed for a collapsing pressure of 250 to 350 kPa, as a rule, 170 kPa is recommended as a maximum for allowable differential pressure.

10.3 Specification Sheet

In addition to the information necessary for a demister gas/liquid separator, which was mentioned in Section 7.3, the following data should also be written in the specification sheet of a gas filter separator:

1) Fluid Filtered.

2) Molecular Mass of Gas and Liquid Density, in kg/m³.

3) Gas Flow Rate, (Range at expected pressures), in m³/day.

4) Turn Down Requirements.

5) Temperature Range, in °C.

6) Normal Liquid Rate, in m³/day.

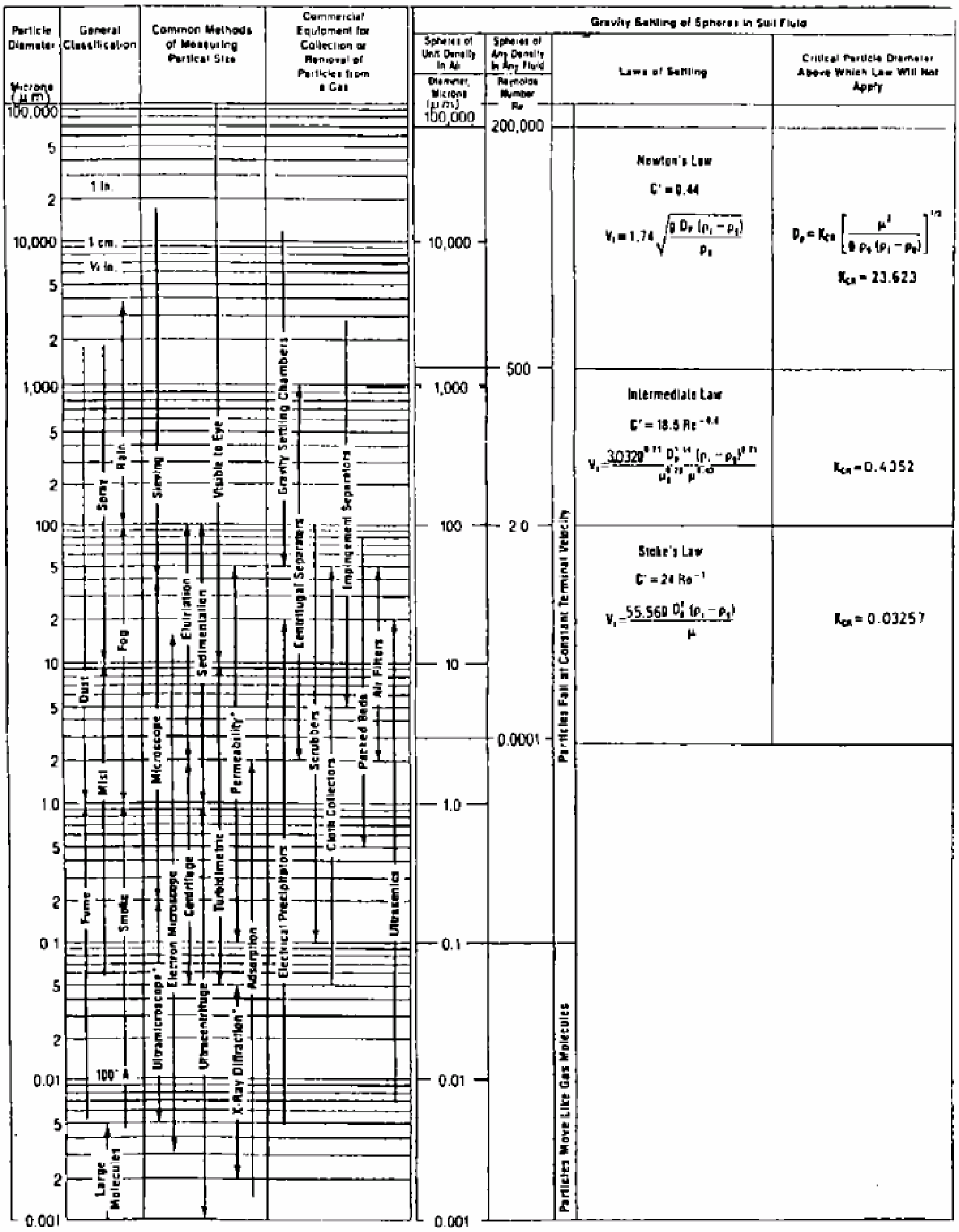
7) Expected Liquid Slug Size.

8) Expected Solid Content.

9) Other Contaminants.

APPENDICES

APPENDIX A

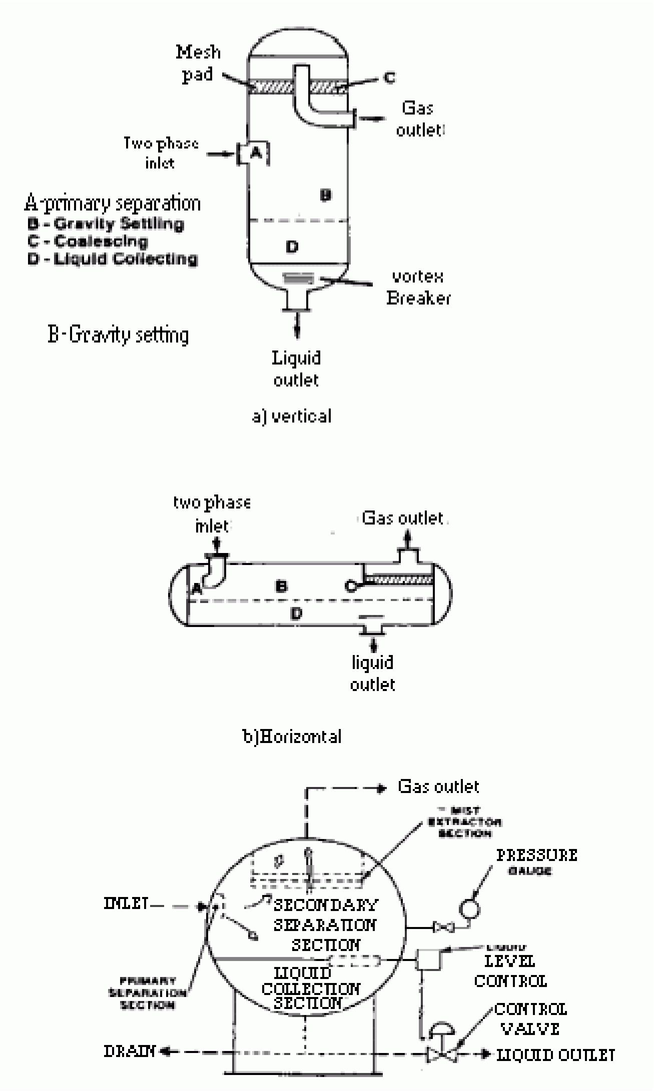


GRAVITY SETTLING LAWS AND PARTICLE CHARACTERISTICS

Fig. A.1

APPENDIX B

1) TYPICAL CONVENTIONAL GAS-LIQUID SEPARATORS

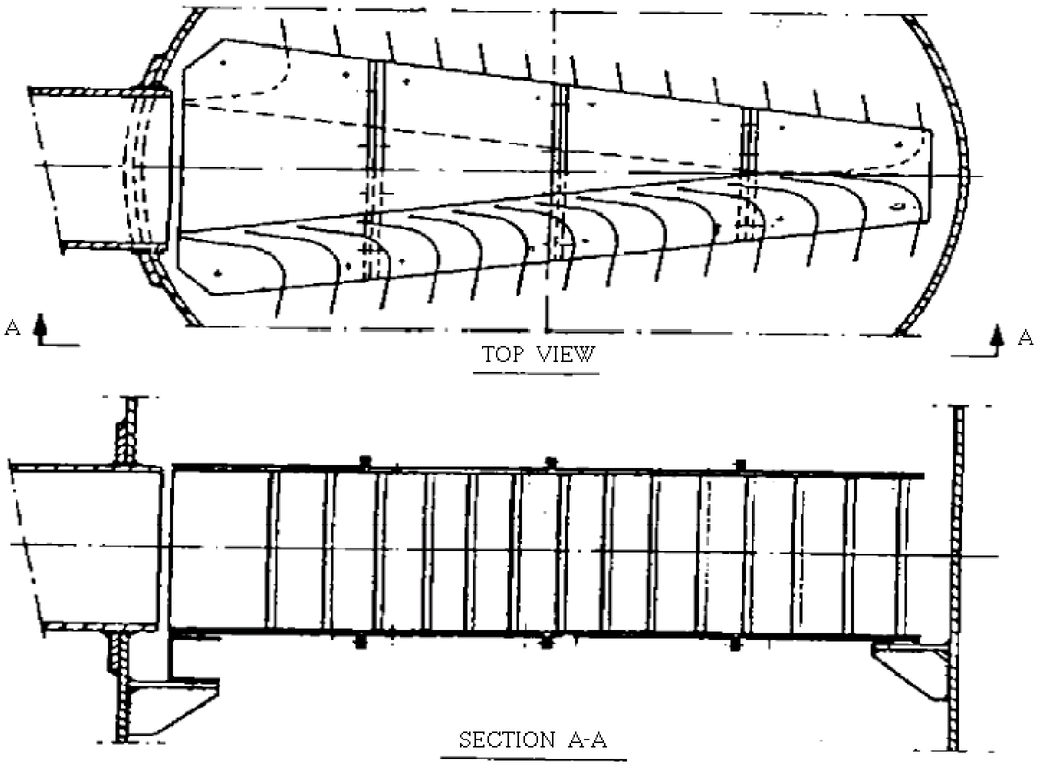


c) Spherical

TYPICAL GAS/LIQUID SEPARATORS

Fig. B.1

APPENDIX C



Note:

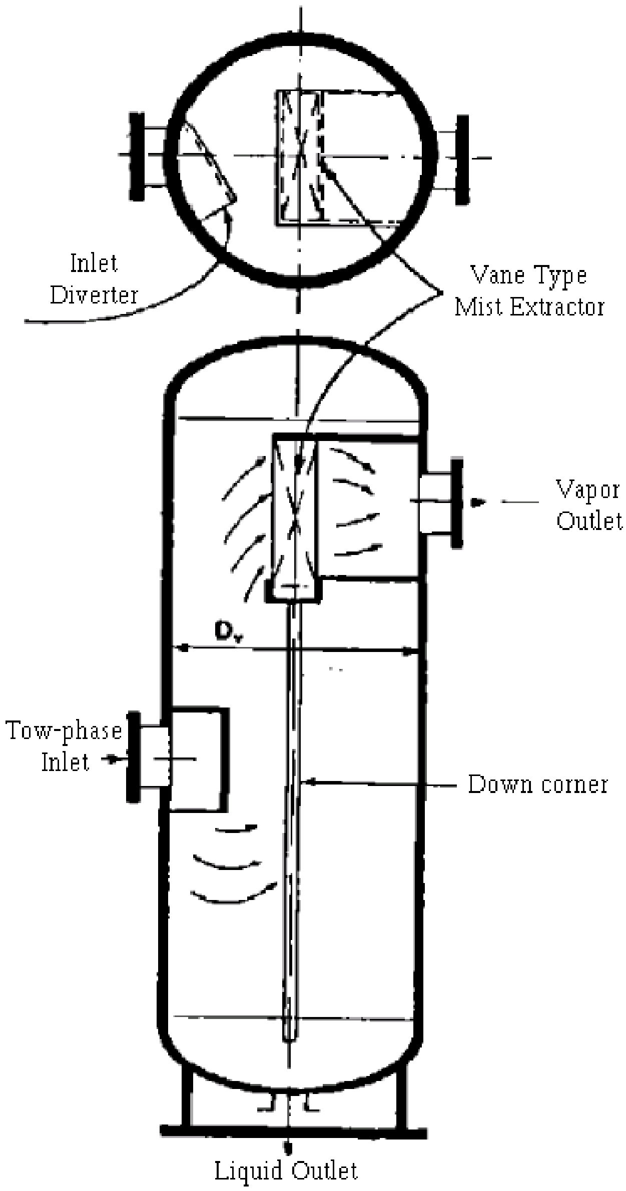
Supports omitted in top view.

TYPICAL VANE TYPE FEED INLET MOUNTED IN A VERTICAL VESSEL

Fig. C.1

APPENDIX D

VANE TYPE MIST EXTRACTOR

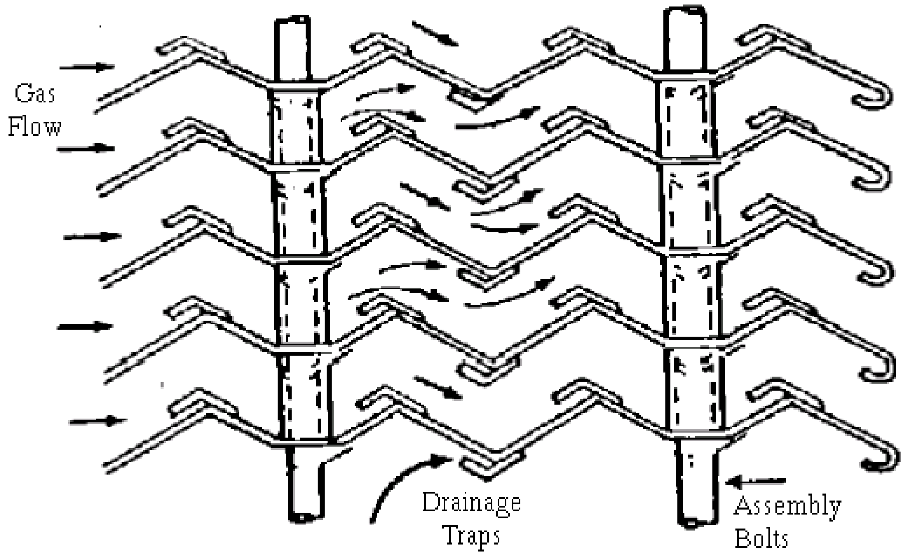


EXAMPLE VERTICAL SEPARATOR WITH VANE TYPE MIST EXTRACTOR

Fig. D.1

(to be continued)

APPENDIX D (continued)

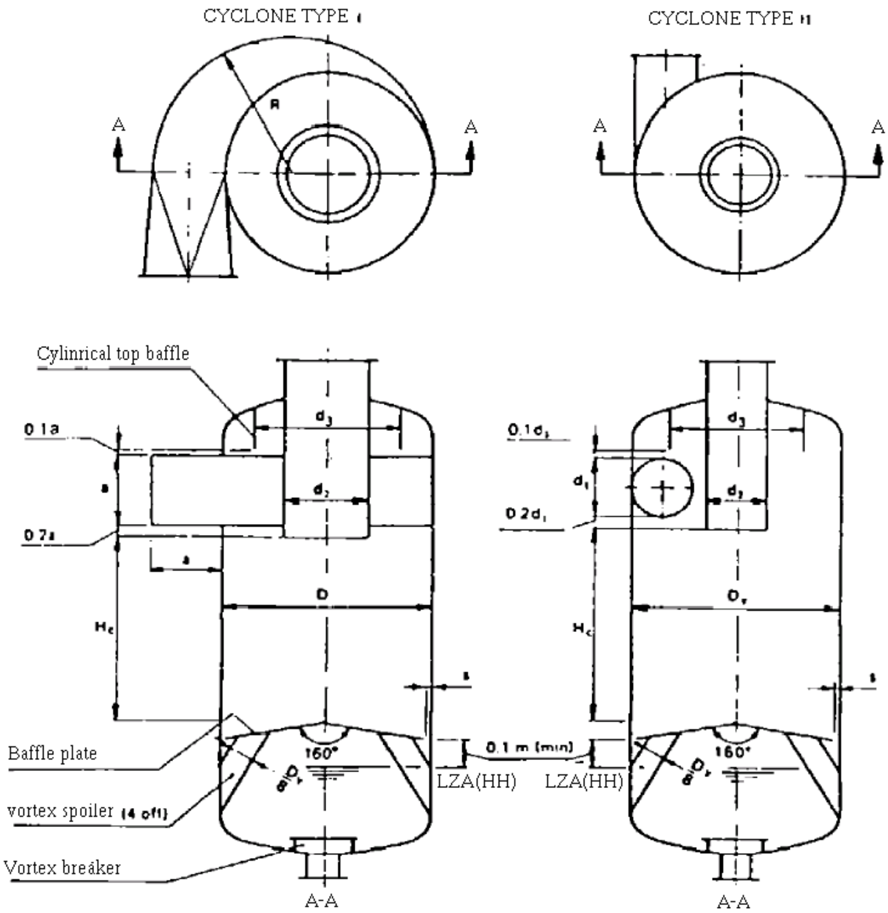


CROSS SECTION OF EXAMPLE VANE ELEMENT MIST EXTRACTOR SHOWING CORRUGATED PLATES WITH LIQUID DRAINAGE TRAPS

Fig. D.2

APPENDIX E

TYPICAL CYCLONE SEPARATORS AND SKETCH OF MULTI-CYCLONE SEPARATOR



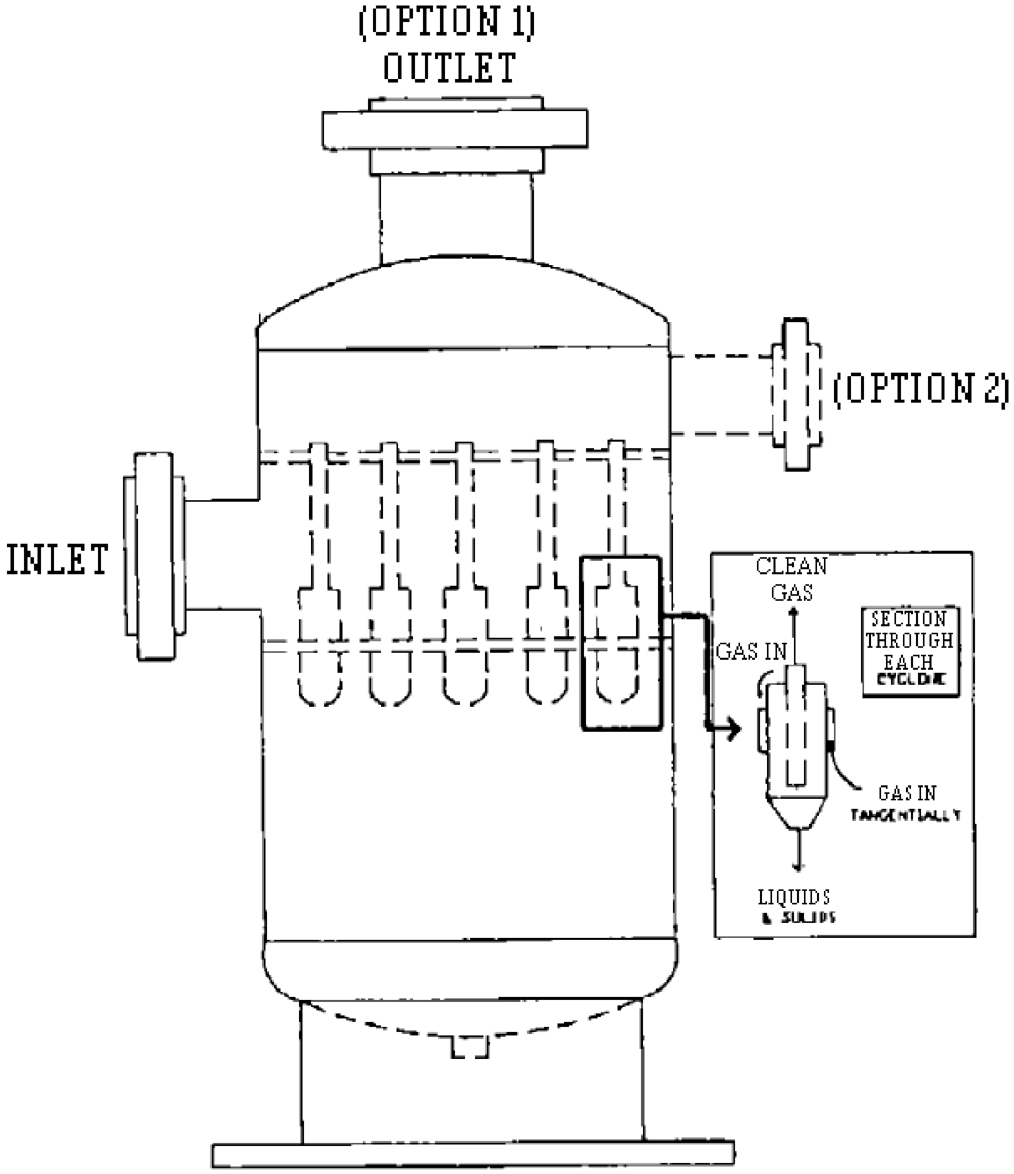
$\frac{n}{4} d_2^2 = a^2$	$d_3 = d_1$
$D\gamma = 25d_1$	$D\gamma = 35\ d_7$
$D_3 = 0.5(D\gamma\ , d_2)$	$d_3 = 0.5\ (D\gamma\ , d_2)$
$S = 0.025\ D\gamma$ (min.10 mm)	$s = 0.025\ D\gamma$ (min.10mm)
$R = 0.5(D\ \forall\exists\ )$	

TYPICAL CYCLONE SEPARATORS

Fig. E.1

(to be continued)

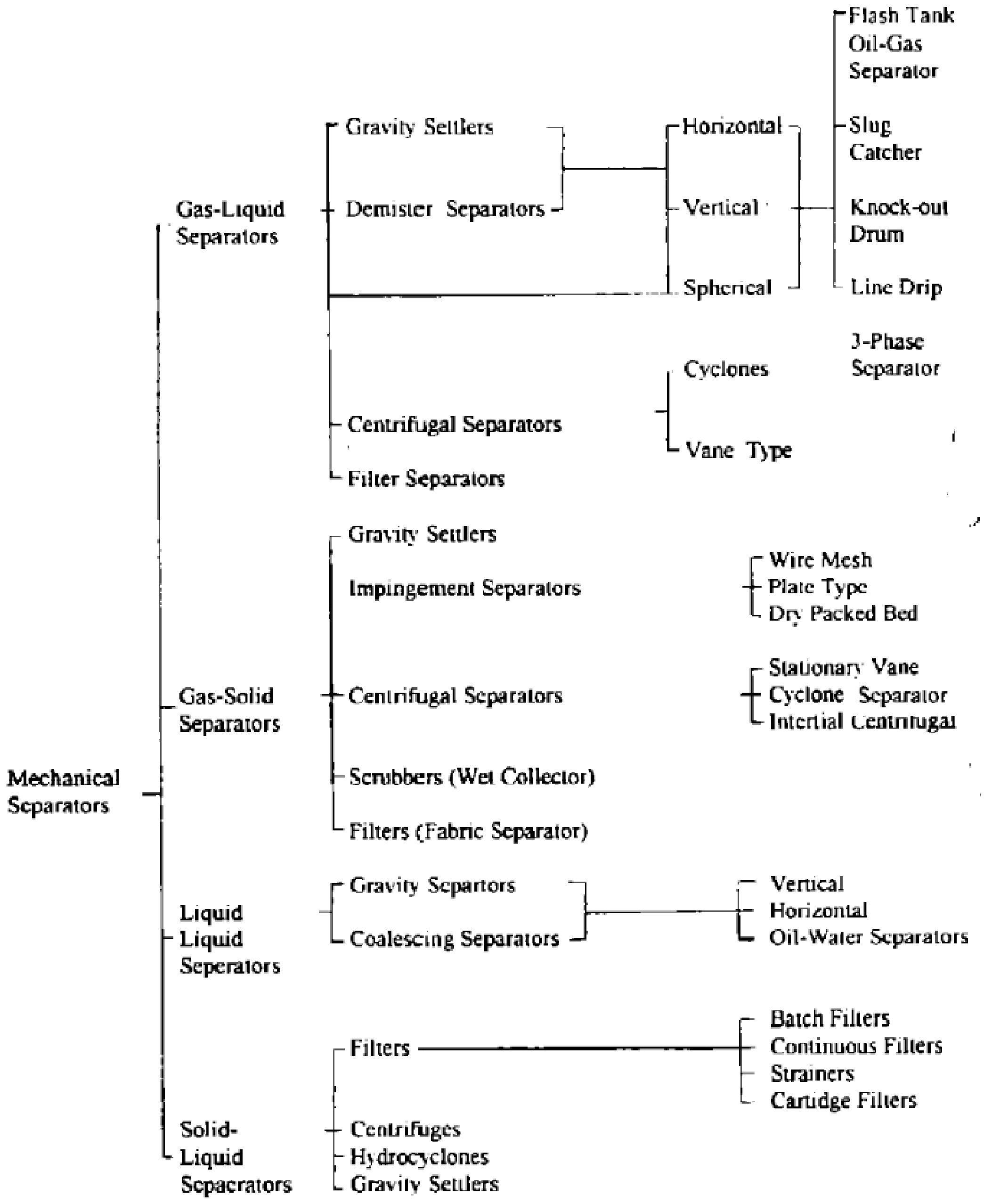
APPENDIX E (continued)



SKETCH OF MULTI-CYCLONE SEPARATOR

Fig. E.2

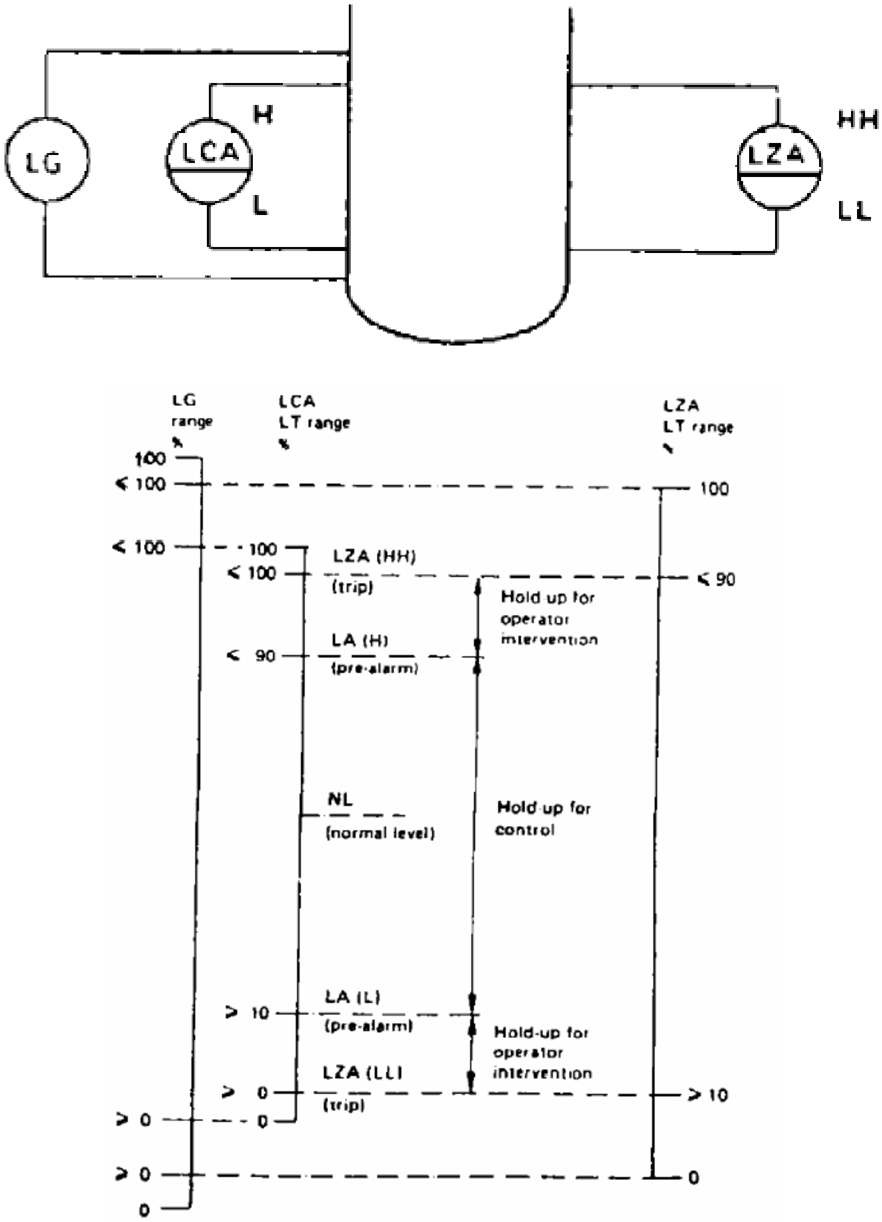
APPENDIX F



TYPES OF MECHANICAL SEPARATORS

Fig. F.1

APPENDIX G



Note:

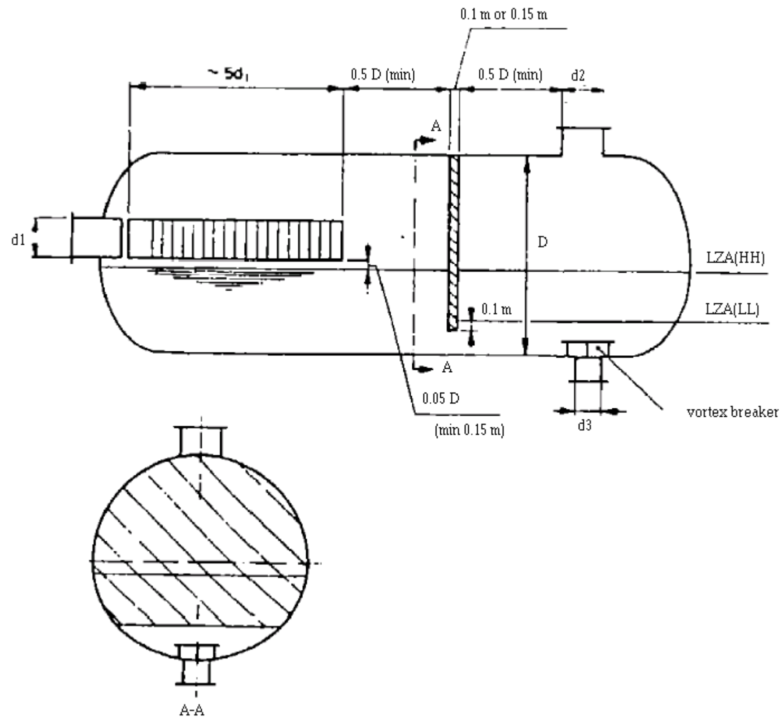
For welding purposes a minimum distance is required between the lower level tappings and the weld of the vessel head. For separator design it will normally be sufficient to assure a distance of 150 mm from centre line of the level tapping to the vessel tangent line.

LIQUID LEVEL CONTROL TERMS

Fig. G.1

(to be continued)

APPENDIX G (continued)



Notes:

1)The liquid hold-up volume is determined by other considerations (see 7.2.4.2). The design method involves trial and error:

L_v and D_v fixed, and a fractional filling chosen to satisfy liquid hold-up requirements. It will then be necessary to check that Q_{max}/A does not exceed 0.15 m/s. A starting value for the ratio L_v/D_v of 3.0 is suggested; values of 2.5 to 6.0 for this ratio are normal.

2) The vertical demister mat shall extend from the top of the vessel to 0.1 m below the LZA (LL) level. The area between the mat and the bottom of the vessel shall be left substantially open, to allow free passage of liquid.

HORIZONTAL DEMISTER VESSEL WITH VERTICAL MAT AND VANE TYPE INLET DEVICE

Fig. G.2

(to be continued)

APPENDIX G (continued)

Legend for Fig. G.1 and Fig. G.2

H	=	High.
HH	=	Very High.
L	=	Low.
LL	=	Very Low.
LA	=	Level Alarm.
LG	=	Level Gage.
LT	=	Level Transmitter.
LCA	=	Level Controller, Alarm Action.
LZA	=	Level Controller, Trip Action.
NL	=	Normal Level.